Supplementary Information

Reef biodiversity data

RLS divers survey reef biodiversity along 50 m transect lines, with multiple transects usually surveyed at each site (often laid parallel at different depths, typically in 4 – 15 m). Two of the three survey methods undertaken by RLS divers along each transect line were used for analyses in this paper: fishes and other large mobile fauna (Method 1), mobile invertebrates and cryptic fishes (Method 2). Fishes, reptiles, mammals and cephalopods are surveyed in duplicate 5 m wide belts on either side of the transect line, with abundance and size recorded for all species observed during a single swim along each side of the line. All species sighted within the blocks are recorded, including unidentified individuals, which are usually photographed for later identification with the assistance of taxonomic experts. Size bins used are 25, 50, 75, 100, 125, 150, 200, 250, 300, 350, 400 and 500 mm total length, with larger individuals estimated to the nearest 125 mm. Fish counts are later converted to biomass estimates using species-specific length-weight relationships provided in Fishbase (fishbase.org).

Large mobile invertebrates (echinoderms, molluscs and crustaceans >2.5 cm) are counted in duplicate 1 m wide belts on either side of the line, with divers brushing aside any vegetation and looking closely in crevices, under ledges or amongst corals. Full details of survey methods are provided in an online methods manual (at http://reeflifesurvey.com).

LTMPA fish data are collected using the same methods as for RLS, but with 4 x 50 m transects laid end on end at each site at either 5 m or 10 m depth. AIMS LTM fish data are also collected along 50 m transects, with 5 transects laid end on end at each site in 6 – 9 m depth. AIMS LTM surveys only include a subset of reef fish species from 10 families (see Emslie et al. 2014; http://www.aims.gov.au/c/document_library/get_file?uuid=29d6a8ae-2ae9-4311-a2de-742d6fdc9a6e&groupId=30301). Fish sizes were recorded for 61 species, including some members of the family Labridae, and all recorded members of Lethrinidae, Lutjanidae and Serranidae, from 2005 onwards.

Sites monitored by AIMS were divided into four regions along the Great Barrier Reef to allow independent examination of regional trends. All monitoring locations assessed using data from the three programs are shown in Figure 1.

Analyses of fishing indicators

All fishing indicators were calculated for each 50 m transect in the RLS database surveyed from 2010-2015 around the Australian continent. Factors gathered for each survey site included whether or not they were in an effective marine protected areas (MPAs), an index of human population density and two metrics of geographic isolation. These were used as

proxies for fishing pressure. Environmental factors were taken from Bio-Oracle (Tyberghein et al. 2012), and included sea surface temperature (SST), SST range, turbidity, and nitrates, while depth of each transect was also included as an environmental factor. Isolation was included using two metrics for each site: the shortest distance by water to the nearest boat ramp, and a shore fishing pressure index. The latter was based on three categories for distance a site was offshore (0 = >500 m, 1 = 100-500 m, 2 = <100 m), and along shore from the nearest road access (0 = >5 km, 1 = 500 m - 5 km, 2 = <500 m). Multiplying the two categories gave an index value that was zero if a site was inaccessible to shore fishing and four if a site was both close to shore and close to a road access point. The human population density index was calculated to provide a relative value of the density of people living within close proximity to each reef site. This involved fitting a smoothly tapered surface to each settlement point on a 2010 world population density grid (CIESIN et al. 2005) using the quadratic kernel function (Silverman 1986), after screening for a density greater than 500 people per 30 arc-second grid cell and with the model boundary set at 100 km.

A linear mixed effects model was used to test for the effects of the four fishing pressure proxies on the spatial distribution of indicator values at RLS sites after accounting for environmental covariates. The ranking procedure based on model results is described in the paper, with key model results provided in Table 1.

Calculating other indicators

B20 is the sum of biomass of all fishes in the 20 cm size class and larger for the whole transect (500 m^2). For AIMS LTM data, only a subset of fish species had size information available for biomass estimates. But given these were consistent between survey years from 2005 and that B20 values were standardised for each site by the maximum value across the time series, trends in B20 shown in Fig. 3 for Great Barrier Reef locations can be considered consistent within locations. They are also largely comparable with other plots, although there is potential for some loss of large fish biomass, associated with species not recorded, to be missed.

The CTI is calculated as a community-weighted mean of the midpoint of the realised thermal range of each fish species on the transect, weighted by the log of their abundance. The midpoint was taken from the values used for Stuart-Smith et al (2015a). The proportion of invasive species was calculated from the individuals of species that are not native to Australia amongst the mobile invertebrates and bottom-dwelling small fishes surveyed in Method 2. The smaller species recorded in Method 2 included all non-native fishes recorded anywhere in Australia, meaning that the addition of fish data from the larger transect blocks surveyed in Method 1 provided no further information relating to this pressure. The threatened species index is calculated using the species list from the combined Method 1 and Method 2 data for a given transect line, as the proportion of those species which are

listed on the IUCN red list under the categories Vulnerable, Endangered, or Critically Endangered.

Mapping indicator values

For a time-integrated spatial assessment, all indicators were calculated using data from individual RLS surveys from 2010-2015, averaged among multiple surveys per site. Values were mapped around Australia using inverse distance weighting interpolation to represent averaged values in regions with dense data points and to interpolate to regions with sparser data points. The interpolation was completed at a resolution 23km by 12km cell size, and values were extended to a maximum of 100 km from survey sites to enable visualisation of a broader strip of colour around the coastline. Values only apply to reef habitats within the coloured areas of maps. The invasive species indicator was zero around most of the continent, and so only individual sites with values >0 were plotted (these are locally concentrated, and so overlap considerably).

Time-series

Data within each dataset were mostly collected in the same season each year, or sometimes across two seasons (e.g. summer/autumn). Any data from a third season were omitted from temporal trend assessments to prevent confounding of seasonal and inter-annual trends. Trends in CTI were based on means of raw values across sites in each year, as values from different locations were all on the same scale (^{o}C). Fishing indicator values differed considerably from site to site, and location to location, so were standardised to the maximum value for each site across the years of survey. The mean standardised values among sites in a given year were plotted.

CTI values calculated using RLS and LTMPA fish data are directly comparable, but the AIMS fish data are based on a subset of species, which could potentially introduce a bias in CTI values if this subset was in any way biased in their geographic distributions in comparison to species not recorded. Such bias would limit the value of comparisons with data from other locations/datasets. To determine and correct for this, CTI values were calculated from the full RLS data from 202 sites along the Great Barrier Reef, and then again from the same RLS data but using only observations of the subset of species (from 10 families) that are recorded in AIMS LTM surveys. Linear regression of the two values from the same sites provided the following correction factor to be applied to CTI values from AIMS surveys for the study:

$$CTI = CTIaims * 0.65 + 9.36$$

Where *CTIaims* is the value of CTI calculated directly from the AIMS LTM data.

References

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